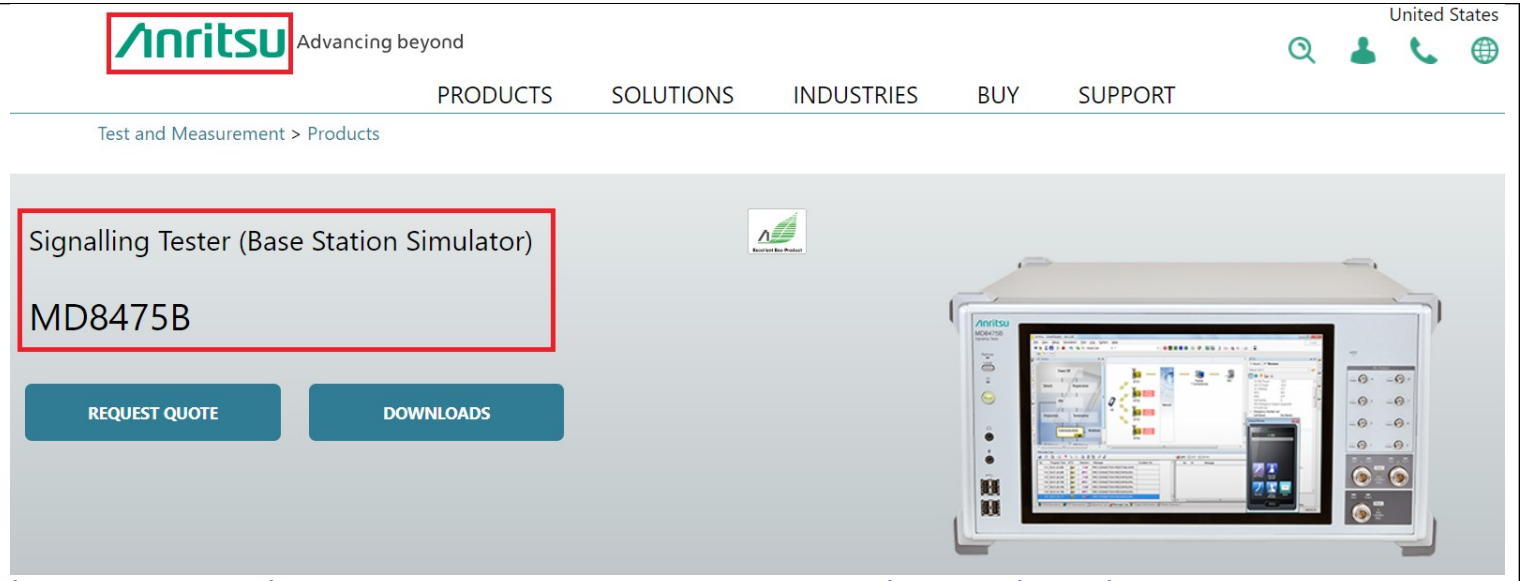
Exhibit 2

Charted Claim: 1

US9578570	Anritsu MD8475B Signalling Tester (Base Station Simulator) (“The accused product”)
1. A method of switching an Instant Messaging (IM)-based first voice call to a second voice call comprising the steps of: receiving an incoming voice call destined for a telephone number, creating a first call record identifying the incoming voice call,	The accused product practices a method of switching an Instant Messaging (IM)-based first voice call (e.g., VOIP call, VoLTE call (E-UTRAN call), etc.) to a second voice call (e.g., UTRAN/GERAN/1xCS call) which comprises the steps of receiving an incoming voice call (e.g., incoming VOIP call, VoLTE call (E-UTRAN call), etc.) destined for a telephone number (e.g., address/number of the called party), creating a first call record (e.g., APN of the VOIP call (E-UTRAN call), GUTI, Bearer information, etc.) identifying the incoming voice call (e.g., incoming VoIP call, VoLTE call (E-UTRAN call), etc.). As shown below, the accused product includes a SmartStudio software that enables testing various calling services such as SRVCC. The SRVCC calling service allows a switch from voice calls made over LTE (E-UTRAN calls, including VoIP calls) to calls on 3G or 2G networks (CS/UTRAN calls). E-UTRAN call acts as the initial IM-based voice call that can be handed off to other networks. When a call is placed to a phone number, a network gateway receives the incoming call and creates a corresponding call record. The initial call made by the accused product (supporting SRVCC) on the E-UTRAN (IM-based) network is established through an ‘Attach’ procedure. During this procedure, the device is assigned a "bearer" for handling calls and data services. Additionally, a Globally Unique Temporary ID (GUTI) is allocated to the user. The network (serving gateway) then stores call information such as the Access Point Name (APN) of the bearer, EPS bearer identity and the user's GUTI. This stored information regarding the bearer, APN, and GUTI effectively constitutes the first call record.



https://www.anritsu.com/en-us/test-measurement/products/md8475b

- Supports multimode terminals
  LTE (2x2 MIMO, 4x4 MIMO), LTE-Advanced (2CA, 3CA, 4CA, 5CA), W-CDMA/HSPA/HSPA Evolution/DC-HSDPA, GSM/GPRS/EGF
  SCDMA/TD-HSPA
- SmartStudio GUI supports easy setup of test environments and functional tests
- Built-in CSCF server function supports GUI-based IMS service tests, such as VoLTE
  - Simple test mode using built-in CSCF server
  - Script mode supporting complex test environments by creating SIP sequences for irregular tests, etc.
- LTE data throughput evaluation environment (DL: 2 Gbps/UL: 150 Mbps)
- All-in-one DC-HSDPA 43.2 Mbps support
- All-in-one support for multi-cell test environment, including Inter-RAT Cell Reselection, Redirection, Cell Change, CS Fallback
- Supports offload tests from LTE/W-CDMA to WLAN
- Automated continuous 24/7 testing using SmartStudio Manager
  - Automatically controls both Android smartphone and MD8475B

https://www.anritsu.com/en-us/test-measurement/products/md8475b

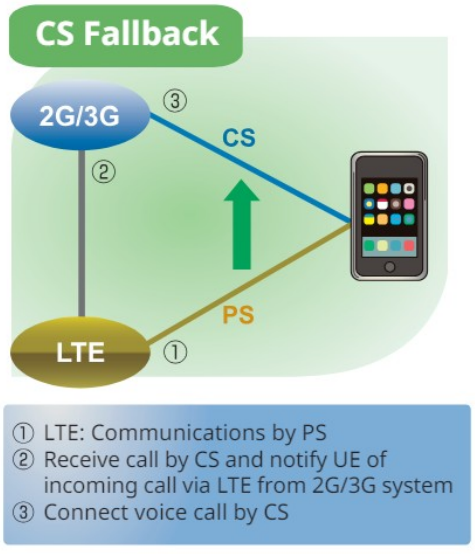
	Mobility Test - Multi-System Configuration SmartStudio supports multi-system simulation without complex test scripts – Cell Selection & Reselection – Handover (Intra/Inter-RAT) • Redirection/Active HO – CSFB/e1xCSFB – SRVCC – Roaming  ***Repeatable simulation impossible on live network*** https://dl.cdn-anritsu.com/en-en/test-measurement/files/Product-Introductions/Product-Introduction/md8475b-el1200.pdf

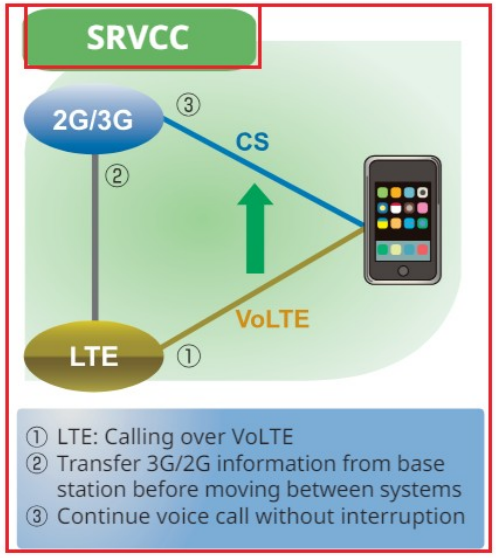
Signalling Tester MD8475B Applications

Voice Call Evaluation Environment

Testing Voice Calls from LTE to 3G/2G

A variety of technologies are used when a UE moves between systems from an LTE to 3G/2G cell. Configuring a 2-cell test environment using SmartStudio supports LTE and 2G/3G system voice call tests such as CS Fallback and SV-LTE (Simultaneous Voice and LTE).





https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

Signalling Tester MD8475B SmartStudio Test Functions

SmartStudio

✓: Supported

Function		Description	MD8475B LTE	MD8475B W-CDMA*2	MD8475B GSM*2	MD8475B TD-SCDMA*2
General						
	Position Registration*1	Connects UE and creates test environment	✓	✓	✓	✓
	L1/L2 Counter	Counts values for each L1/L2 channel every second	✓	✓	–	✓
	Throughput Counter	Simultaneously displays PHY layer and IP Throughput (SDU)	✓	✓	✓	✓
	Trace	Displays events for each layer as arrows	✓	✓	✓	✓
	Reject	Returns arbitrary reject message when UE connected	✓	✓	✓	✓
	Neighbor Cell Setting	Reports information to UE about BTS adjacent to BTS under test	✓	✓	✓	✓
	RF Related					
		TRx Power Setting	Changes TRx power of BTS during Idle Communication	✓	✓	✓	✓
		No Network Setting	Sets BTS Power output to OFF and switches UE to no network status	✓	✓	✓	✓
		RF Monitor	Displays frequency, frequency error, and power for each channel such as PDSCH, PUSCH, etc.	✓	✓	✓	✓
		TPC Setting	Changes TPC (Transmit Power Control) arbitrarily	✓	✓	✓	✓
		AWGN	Sends AWGN in conjunction with normal signal	✓	✓	–	–
		RF Measurement Options	Measures UE RF power at each second	✓	✓	✓	–
	External Control						
		Ethernet	Controls SmartStudio operation (parameter selection, start, etc.) from external PC	✓	✓	✓	✓
		GPIB	Controls SmartStudio setting parameters from external PC	✓	✓	✓	✓
Voice/Video Communications							
	LTE FDD/TDD						
		VoLTE/Video Telephony Calling/Answering (Loopback)	Executes call test for UE supporting Voice over LTE/Video over LTE	✓			
		Emergency Call/Originating System	Sets emergency call, and VoLTE/Video call control at LTE	✓			
		Codec Change	Changes audio and video codecs arbitrarily and executes UE switchover test	✓			
	LTE FDD/TDD, W-CDMA, GSM, TD-SCDMA						
		CSFB/eCSFB*3	Auto-switches communication method when other system voice call received during LTE call	✓	✓	✓	✓
		SRVCC*3	Performs seamless switch to CS voice call during VoLTE call	✓	✓	✓	–

https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

This document specifies the architecture enhancements for Single Radio Voice Call Continuity (SRVCC) between the following access systems for voice calls that are anchored in the IMS:

- from E-UTRAN to 3GPP2 1xCS;
- from E-UTRAN to UTRAN/GERAN;
- from UTRAN (HSPA) to UTRAN/GERAN.
- from UTRAN/GERAN to E-UTRAN.
- from GERAN to UTRAN (HSPA).
- from NG-RAN to UTRAN.

This document will not describe 3GPP2 functional entities. However, interfaces between both 3GPP and 3GPP2 functional entities are described in this specification.

SRVCC from E-UTRAN access to 3GPP2 1xCS is covered in this specification, including the handling of IMS emergency call continuity. Handling of non-voice component and SRVCC from 3GPP2 1xCS to E-UTRAN direction is not specified in this release.

SRVCC from NG-RAN/E-UTRAN/UTRAN (HSPA) access and 3GPP UTRAN/GERAN CS accesses for voice calls that are anchored in the IMS, as well as the coordination between the SRVCC for voice call and the handover of non-voice PS bearers are covered in this specification. SRVCC with IMS emergency call continuity from E-UTRAN/UTRAN (HSPA) to 3GPP UTRAN/GERAN CS accesses and from NG-RAN to UTRAN for voice calls is covered in this specification. SRVCC with eCall over IMS continuity from E-UTRAN/UTRAN (HSPA) to 3GPP UTRAN/GERAN CS accesses is covered in this specification. SRVCC with priority handling from E-UTRAN to 3GPP UTRAN/GERAN CS accesses for voice or voice and video calls is also covered in this specification. The handover of non-voice PS bearer from E-UTRAN is specified by the procedures defined in TS 23.401 [2], TS 23.060 [10], TS 25.413 [11] and TS 43.129 [12]. The handover of non-voice PS bearer from UTRAN (HSPA) is specified by the procedures defined in TS 23.060 [10], TS 25.413 [11] and TS 43.129 [12]. The handover of non-voice PS bearer from NG-RAN to UTRAN is not supported.

This document specifies the architecture enhancements for Single Radio Video Call Continuity (vSRVCC) from E-UTRAN to UTRAN-CS access for Video Calls that are anchored in the IMS.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

	3GPP SRVCC UE: A 3GPP SRVCC UE is a UE enhanced for IMS Service Continuity with the additional UE capabilities described in this specification for SRVCC NG-RAN to 3GPP UTRAN and / or between E-UTRAN and 3GPP UTRAN and / or between E-UTRAN and 3GPP GERAN and / or between UTRAN (HSPA) and 3GPP UTRAN and 3GPP GERAN. **Correlation MSISDN:** An MSISDN used for correlation of sessions. See TS 23.003 [27] for more information. **Emergency Session Transfer Number for SRVCC (E-STN-SR):** see TS 23.237 [14]. **IMS-based MPS Session:** see TS 23.401 [2]. **Session Transfer Number for SRVCC (STN-SR):** see TS 23.237 [14]. **Single Radio Voice Call Continuity (SRVCC):** Voice call continuity between IMS over PS access and CS access for calls that are anchored in IMS when the UE is capable of transmitting/receiving on only one of those access networks at a given time. **Single Radio Video Call Continuity (vSRVCC):** Video call continuity from E-UTRAN to UTRAN-CS for calls that are anchored in the IMS when the UE is capable of transmitting/receiving on only one of those access networks at a https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

6.1 SRVCC from E-UTRAN to 3GPP2 1xCS

6.1.1 E-UTRAN Attach procedure for SRVCC

E-UTRAN attach, emergency attach, or tracking area update procedure for 3GPP2 SRVCC UE is performed as defined in TS 23.401 [2] with the following additions:

- SRVCC UE includes the SRVCC capability indication as part of the "UE Network Capability" in the Attach Request message or Tracking Area Update Request message. MME stores this information for SRVCC operation.
- SRVCC UE capable for IMS emergency calls shall include the SRVCC capability indication as part of the UE network capability in the Emergency Attach Request message. MME stores this information for emergency SRVCC operation.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

11. During the execution of the Session Transfer procedure the remote end is updated with the SDP of the CS access leg. The downlink flow of VoIP packets is switched towards the CS access leg at this point.
12. Source IMS access leg is released as per TS 23.237 [14].

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

5.3.2 Attach procedure

5.3.2.1 E-UTRAN Initial Attach

A UE/user needs to register with the network to receive services that require registration. This registration is described as Network Attachment. The always-on connectivity for UE/users of the EPS may be enabled by establishing a default EPS bearer during Network Attachment. The PCC rules applied to the default EPS bearer may be predefined in the PDN GW and activated in the attachment by the PDN GW itself. The Attach procedure may trigger one or multiple Dedicated Bearer Establishment procedures to establish dedicated EPS bearer(s) for that UE. During the attach procedure, the UE may request for an IP address allocation. Terminals utilising only IETF based mechanisms for IP address allocation are also supported.

During the Initial Attach procedure the Mobile Equipment Identity is obtained from the UE. The MME operator may check the ME Identity with an EIR. The MME passes the ME Identity (IMEISV) to the HSS and to the PDN GW.

During the Initial Attach procedure, if the MME supports SRVCC and if any of the conditions described in step 8 in Figure 5.3.2.1-1 are satisfied, the MME informs the HSS with the UE SRVCC capability e.g. for further IMS registration.

https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf

13. The Serving GW creates a new entry in its EPS Bearer table and sends a Create Session Request (IMSI, MSISDN, APN, Serving GW Address for the user plane, Serving GW TEID of the user plane, Serving GW TEID of the control plane, RAT type, Default EPS Bearer QoS, PDN Type, PDN Address, subscribed APN-AMBR, EPS Bearer Identity, Protocol Configuration Options, Handover Indication, ME Identity, User Location Information (ECGI), UE Time Zone, User CSG Information, MS Info Change Reporting support indication, PDN Charging Pause Support indication, Selection Mode, Charging Characteristics, Trace Reference, Trace Type, Trigger Id, OMC Identity, Maximum APN Restriction, Dual Address Bearer Flag, Serving Network, APN Rate Control Status) message to the PDN GW indicated by the PDN GW address received in the previous step. After this step, the Serving GW buffers any downlink packets it may receive from the PDN GW without sending a Downlink Data Notification message to the MME until it receives the Modify Bearer Request message in step 23 below. The MSISDN is included if received from the MME.

	https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf The new MME sends an Attach Accept (GUTI, TAI List, Session Management Request (APN, PDN Type, PDN Address, EPS Bearer Identity, Protocol Configuration Options, Header Compression Configuration, Control Plane Only Indicator), NAS sequence number, NAS-MAC, IMS Voice over PS session supported Indication, Emergency Service Support indicator, LCS Support Indication, Supported Network Behaviour, Service Gap https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf 18. If the eNodeB received an S1-AP Initial Context Setup Request the eNodeB sends the RRC Connection Reconfiguration message including the EPS Radio Bearer Identity to the UE, and the Attach Accept message will be sent along to the UE. If the eNodeB received an S1-AP Downlink NAS Transport message (e.g. containing the Attach Accept message), the eNode B sends a RRC Direct Transfer message to the UE. The UE shall store the QoS Negotiated, Radio Priority, Packet Flow Id and TI, which it received in the Session Management Request, for use when accessing via GERAN or UTRAN. The APN is provided to the UE to notify it of the APN for which the activated default bearer is associated. For further details, see TS 36.331 [37]. The UE may provide EPS Bearer QoS parameters to the application handling the traffic flow(s). The application usage of the EPS Bearer QoS is implementation dependent. The UE shall not reject the RRC Connection Reconfiguration on the basis of the EPS Bearer QoS parameters contained in the Session Management Request. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf
establishing over an IM voice network an IM-based first voice	The accused product practices establishing over an IM voice network (e.g., VOIP (E-UTRAN) network) an IM-based first voice call (e.g., VOIP call, VoLTE call (E-UTRAN call), etc.) with an IM phone agent (e.g., SRVCC enabled UE device), including in the first call record first information about the IM-based first voice call (e.g., APN, GUTI, EPS bearer identity, etc.) connecting the incoming voice call to the IM-based first voice call (e.g., incoming call is identified and processed as VOIP call, VoLTE call (E-UTRAN call), etc.).

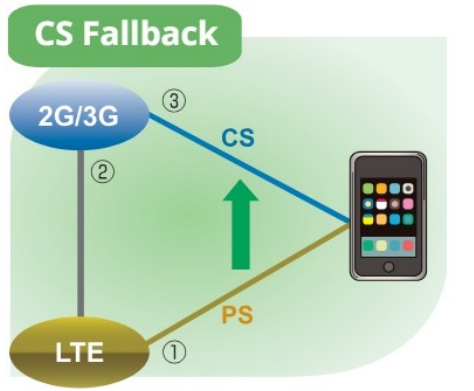
call with an IM phone agent, including in the first call record first information about the IM-based first voice call, connecting the incoming voice call to the IM-based first voice call,	As shown below, SRVCC utilizes 'Attach' procedures to establish a call, with the initial IM-based call being set up over the IMS network. Information about the EPS bearer, APN and GUTI associated with this IM call is then stored in the gateway, forming the initial call record. This record includes the first set of call details. During the establishment of an IM call, the user device receives both a bearer allocation and a Globally Unique Temporary ID (GUTI). The serving gateway stores information specific to this initial IM-based voice call, such as the Access Point Name (APN) of the bearer, EPS bearer identity and the user's GUTI. This stored information, encompassing the Attach Accept message with bearer details, APN, and the user's GUTI, essentially constitutes the first information of the first call record.

Signalling Tester MD8475B Applications

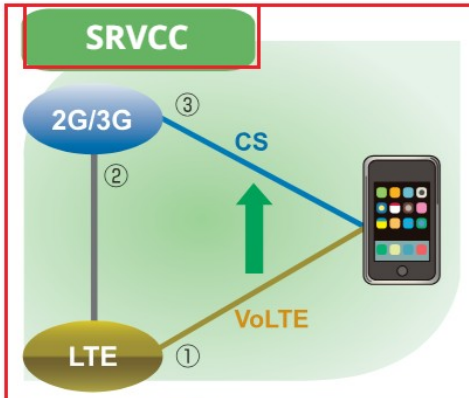
Voice Call Evaluation Environment

Testing Voice Calls from LTE to 3G/2G

A variety of technologies are used when a UE moves between systems from an LTE to 3G/2G cell. Configuring a 2-cell test environment using SmartStudio supports LTE and 2G/3G system voice call tests such as CS Fallback and SV-LTE (Simultaneous Voice and LTE).



① LTE: Communications by PS
② Receive call by CS and notify UE of incoming call via LTE from 2G/3G system
③ Connect voice call by CS



① LTE: Calling over VoLTE
② Transfer 3G/2G information from base station before moving between systems
③ Continue voice call without interruption

https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

Signalling Tester MD8475B SmartStudio Test Functions

SmartStudio

✓: Supported

Function		Description	MD8475B LTE	MD8475B W-CDMA*2	MD8475B GSM*2	MD8475B TD-SCDMA*2
General						
	Position Registration*1	Connects UE and creates test environment	✓	✓	✓	✓
	L1/L2 Counter	Counts values for each L1/L2 channel every second	✓	✓	–	✓
	Throughput Counter	Simultaneously displays PHY layer and IP Throughput (SDU)	✓	✓	✓	✓
	Trace	Displays events for each layer as arrows	✓	✓	✓	✓
	Reject	Returns arbitrary reject message when UE connected	✓	✓	✓	✓
	Neighbor Cell Setting	Reports information to UE about BTS adjacent to BTS under test	✓	✓	✓	✓
	RF Related					
		TRx Power Setting	Changes TRx power of BTS during Idle Communication	✓	✓	✓	✓
		No Network Setting	Sets BTS Power output to OFF and switches UE to no network status	✓	✓	✓	✓
		RF Monitor	Displays frequency, frequency error, and power for each channel such as PDSCH, PUSCH, etc.	✓	✓	✓	✓
		TPC Setting	Changes TPC (Transmit Power Control) arbitrarily	✓	✓	✓	✓
		AWGN	Sends AWGN in conjunction with normal signal	✓	✓	–	–
		RF Measurement Options	Measures UE RF power at each second	✓	✓	✓	–
	External Control					
		Ethernet	Controls SmartStudio operation (parameter selection, start, etc.) from external PC	✓	✓	✓	✓
		GPIB	Controls SmartStudio setting parameters from external PC	✓	✓	✓	✓
Voice/Video Communications						
	LTE FDD/TDD					
		VoLTE/Video Telephony Calling/Answering (Loopback)	Executes call test for UE supporting Voice over LTE/Video over LTE	✓			
		Emergency Call/Originating System	Sets emergency call, and VoLTE/Video call control at LTE	✓			
		Codec Change	Changes audio and video codecs arbitrarily and executes UE switchover test	✓			
	LTE FDD/TDD, W-CDMA, GSM, TD-SCDMA					
		CSFB/eCSFB*3	Auto-switches communication method when other system voice call received during LTE call	✓	✓	✓	✓
		SRVCC*3	Performs seamless switch to CS voice call during VoLTE call	✓	✓	✓	–

https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

	6.1 SRVCC from E-UTRAN to 3GPP2 1xCS 6.1.1 E-UTRAN Attach procedure for SRVCC E-UTRAN attach, emergency attach, or tracking area update procedure for 3GPP2 SRVCC UE is performed as defined in TS 23.401 [2] with the following additions: - SRVCC UE includes the SRVCC capability indication as part of the "UE Network Capability" in the Attach Request message or Tracking Area Update Request message. MME stores this information for SRVCC operation. - SRVCC UE capable for IMS emergency calls shall include the SRVCC capability indication as part of the UE network capability in the Emergency Attach Request message. MME stores this information for emergency SRVCC operation. https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

Figure 6.1.3-1 illustrates a high-level call flow for the E-UTRAN-to-1x voice service continuity procedure.

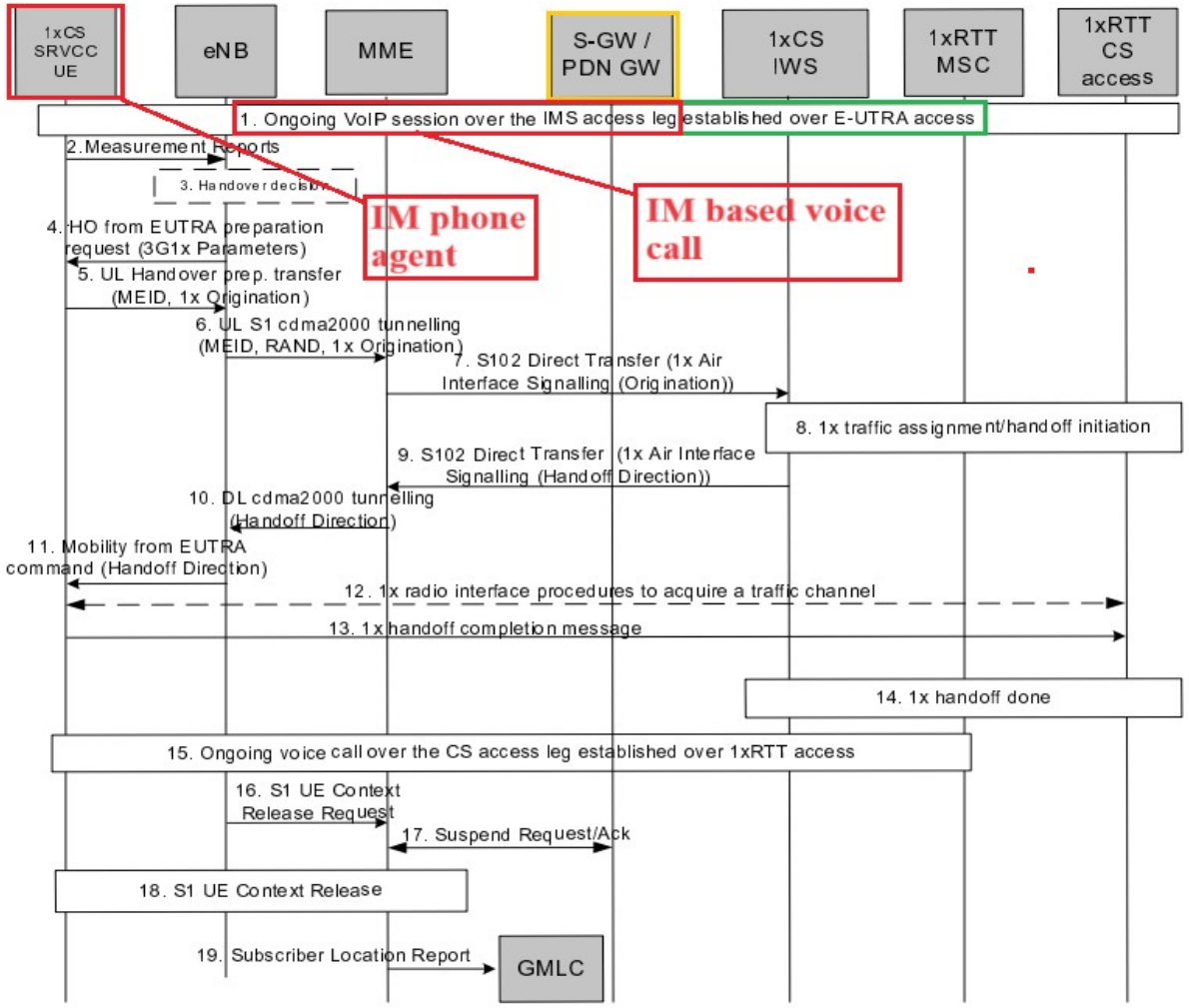


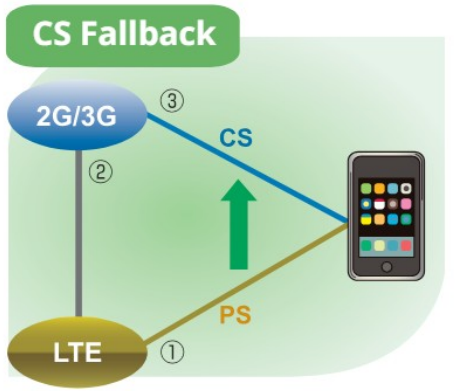
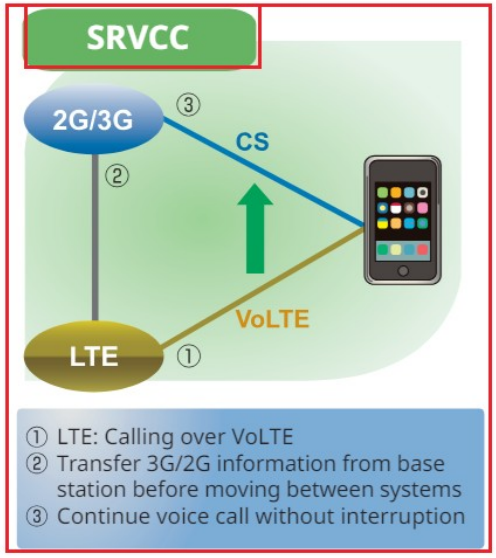
Figure 6.1.3-1: LTE VoIP-to-1x CS voice service continuity

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

	5.3.2 Attach procedure 5.3.2.1 E-UTRAN Initial Attach A UE/user needs to register with the network to receive services that require registration. This registration is described as Network Attachment. The always-on connectivity for UE/users of the EPS may be enabled by establishing a default EPS bearer during Network Attachment. The PCC rules applied to the default EPS bearer may be predefined in the PDN GW and activated in the attachment by the PDN GW itself. The Attach procedure may trigger one or multiple Dedicated Bearer Establishment procedures to establish dedicated EPS bearer(s) for that UE. During the attach procedure, the UE may request for an IP address allocation. Terminals utilising only IETF based mechanisms for IP address allocation are also supported. During the Initial Attach procedure the Mobile Equipment Identity is obtained from the UE. The MME operator may check the ME Identity with an EIR. The MME passes the ME Identity (IMEISV) to the HSS and to the PDN GW. During the Initial Attach procedure, if the MME supports SRVCC and if any of the conditions described in step 8 in Figure 5.3.2.1-1 are satisfied, the MME informs the HSS with the UE SRVCC capability e.g. for further IMS registration. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf

	13. The Serving GW creates a new entry in its EPS Bearer table and sends a Create Session Request (IMSI, MSISDN, APN, Serving GW Address for the user plane, Serving GW TEID of the user plane, Serving GW TEID of the control plane, RAT type, Default EPS Bearer QoS, PDN Type, PDN Address, subscribed APN-AMBR, EPS Bearer Identity, Protocol Configuration Options, Handover Indication, ME Identity, User Location Information (ECGI), UE Time Zone, User CSG Information, MS Info Change Reporting support indication, PDN Charging Pause Support indication, Selection Mode, Charging Characteristics, Trace Reference, Trace Type, Trigger Id, OMC Identity, Maximum APN Restriction, Dual Address Bearer Flag, Serving Network, APN Rate Control Status) message to the PDN GW indicated by the PDN GW address received in the previous step. After this step, the Serving GW buffers any downlink packets it may receive from the PDN GW without sending a Downlink Data Notification message to the MME until it receives the Modify Bearer Request message in step 23 below. The MSISDN is included if received from the MME. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf The new MME sends an Attach Accept (GUTI, TAI List, Session Management Request (APN, PDN Type, PDN Address, EPS Bearer Identity, Protocol Configuration Options, Header Compression Configuration, Control Plane Only Indicator), NAS sequence number, NAS-MAC, IMS Voice over PS session supported Indication, Emergency Service Support indicator, LCS Support Indication, Supported Network Behaviour, Service Gap https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf

	18. If the eNodeB received an S1-AP Initial Context Setup Request the eNodeB sends the RRC Connection Reconfiguration message including the EPS Radio Bearer Identity to the UE, and the Attach Accept message will be sent along to the UE. If the eNodeB received an S1-AP Downlink NAS Transport message (e.g. containing the Attach Accept message), the eNode B sends a RRC Direct Transfer message to the UE. The UE shall store the QoS Negotiated, Radio Priority, Packet Flow Id and TI, which it received in the Session Management Request, for use when accessing via GERAN or UTRAN. The APN is provided to the UE to notify it of the APN for which the activated default bearer is associated. For further details, see TS 36.331 [37]. The UE may provide EPS Bearer QoS parameters to the application handling the traffic flow(s). The application usage of the EPS Bearer QoS is implementation dependent. The UE shall not reject the RRC Connection Reconfiguration on the basis of the EPS Bearer QoS parameters contained in the Session Management Request. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf
sending at least a portion of the first call record to a switchover agent, creating a second call record associated with the telephone number including the at least	The accused product practices sending at least a portion of the first call record (e.g., APN of the VOIP call (E-UTRAN call), GUTI, Bearer information, etc.) to a switchover agent (e.g., a network function to switch VOIP call (E-UTRAN call) such as GW, IWS, MSC, CS, etc.), creating a second call record associated with the telephone number (e.g., UTRAN/GERAN call) including the at least a portion of the first call record (e.g., APN of the VOIP call (E-UTRAN call), GUTI, Bearer information, etc.) and second information about the IM-based first voice call (e.g., port information of the VOIP call (E-UTRAN call)). As per general disclosure, a cellular UE utilizes port numbers during IM-based calls. This is the second information pertaining to the IM call stored at the network. A portion of the first call record (APN and GUTI details) is transmitted to the user's device. This information, combined with the port numbers related to the IM call stored at the network, forms the second call record. The network sends the call related information i.e., a first call record, APN, bearer information, GUTI, etc., to a network function for handover.

a portion of the first call record and second information about the IM-based first voice call,	**Signalling Tester MD8475B Applications** **Voice Call Evaluation Environment** **Testing Voice Calls from LTE to 3G/2G** A variety of technologies are used when a UE moves between systems from an LTE to 3G/2G cell. Configuring a 2-cell test environment using SmartStudio supports LTE and 2G/3G system voice call tests such as CS Fallback and SV-LTE (Simultaneous Voice and LTE).   https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

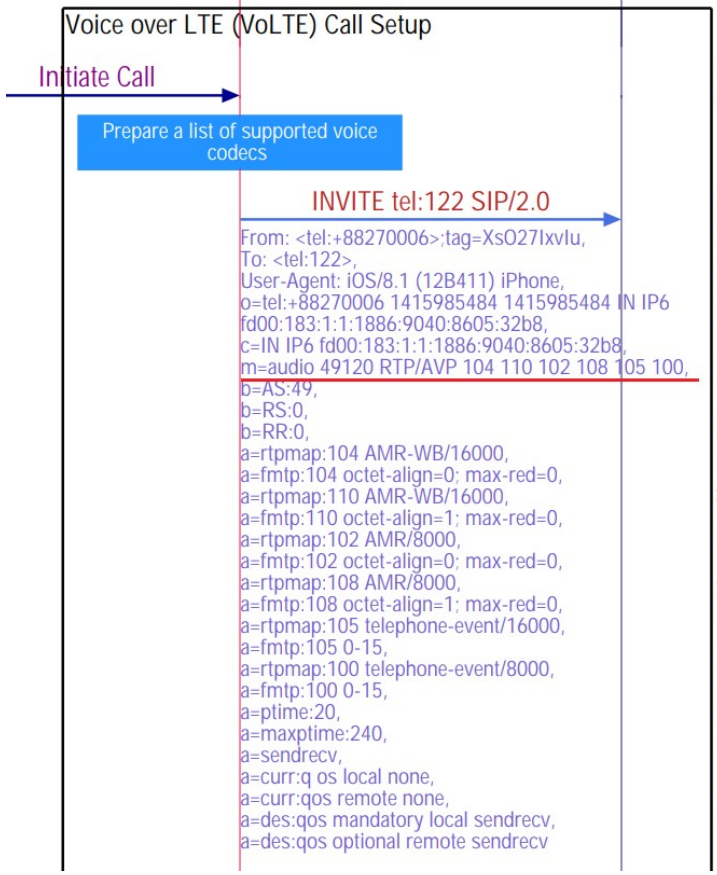
Signalling Tester MD8475B SmartStudio Test Functions

SmartStudio

✓: Supported

Function		Description	MD8475B LTE	MD8475B W-CDMA*2	MD8475B GSM*2	MD8475B TD-SCDMA*2
General						
	Position Registration*1	Connects UE and creates test environment	✓	✓	✓	✓
	L1/L2 Counter	Counts values for each L1/L2 channel every second	✓	✓	–	✓
	Throughput Counter	Simultaneously displays PHY layer and IP Throughput (SDU)	✓	✓	✓	✓
	Trace	Displays events for each layer as arrows	✓	✓	✓	✓
	Reject	Returns arbitrary reject message when UE connected	✓	✓	✓	✓
	Neighbor Cell Setting	Reports information to UE about BTS adjacent to BTS under test	✓	✓	✓	✓
	RF Related					
		TRx Power Setting	Changes TRx power of BTS during Idle Communication	✓	✓	✓	✓
		No Network Setting	Sets BTS Power output to OFF and switches UE to no network status	✓	✓	✓	✓
		RF Monitor	Displays frequency, frequency error, and power for each channel such as PDSCH, PUSCH, etc.	✓	✓	✓	✓
		TPC Setting	Changes TPC (Transmit Power Control) arbitrarily	✓	✓	✓	✓
		AWGN	Sends AWGN in conjunction with normal signal	✓	✓	–	–
		RF Measurement Options	Measures UE RF power at each second	✓	✓	✓	–
	External Control					
		Ethernet	Controls SmartStudio operation (parameter selection, start, etc.) from external PC	✓	✓	✓	✓
		GPIB	Controls SmartStudio setting parameters from external PC	✓	✓	✓	✓
Voice/Video Communications						
	LTE FDD/TDD					
		VoLTE/Video Telephony Calling/Answering (Loopback)	Executes call test for UE supporting Voice over LTE/Video over LTE	✓			
		Emergency Call/Originating System	Sets emergency call, and VoLTE/Video call control at LTE	✓			
		Codec Change	Changes audio and video codecs arbitrarily and executes UE switchover test	✓			
	LTE FDD/TDD, W-CDMA, GSM, TD-SCDMA					
		CSFB/eCSFB*3	Auto-switches communication method when other system voice call received during LTE call	✓	✓	✓	✓
		SRVCC*3	Performs seamless switch to CS voice call during VoLTE call	✓	✓	✓	–

https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf



The subscriber initiates a voice call.

The iPhone initiates that call with a SIP Invite message. The QoS information signaled in the message is:

`o=tel:+88270006 1415985484 1415985484 IN IP6 fd00:183:1:1:1886:9040:8605:32b8`
Specifies that the caller is +88270006 with 1415985484 session id. The caller uses the Internet (IN). The IPv6 address for the caller is also included.

`c=IN IP6 fd00:183:1:1:1886:9040:8605:32b8`
The connection is being initiated from the specified address.

`m=audio 49120 RTP/AVP 104 110 102 108 105 100`
Specifies that port number 49120 is assigned for audio with a list of supported media type formats (104, 110, 102, 108, 105, and 100).

`b=AS:49`
Specifies maximum Application Specific bandwidth as 49 Kbps.

`a=rtpmap:104 AMR-WB/16000`
Specifies a AMR-WB codec with 16000 bps. The media type of the codec is 104.

`a=fmtp:104 octet-align=0; max-red=0`
Specifies additional parameters for format code 104.

`a=sendrecv`
Specifies that the session will be sending and receiving media.

https://www.eventhelix.com/lte/volte/volte-originating-call.pdf

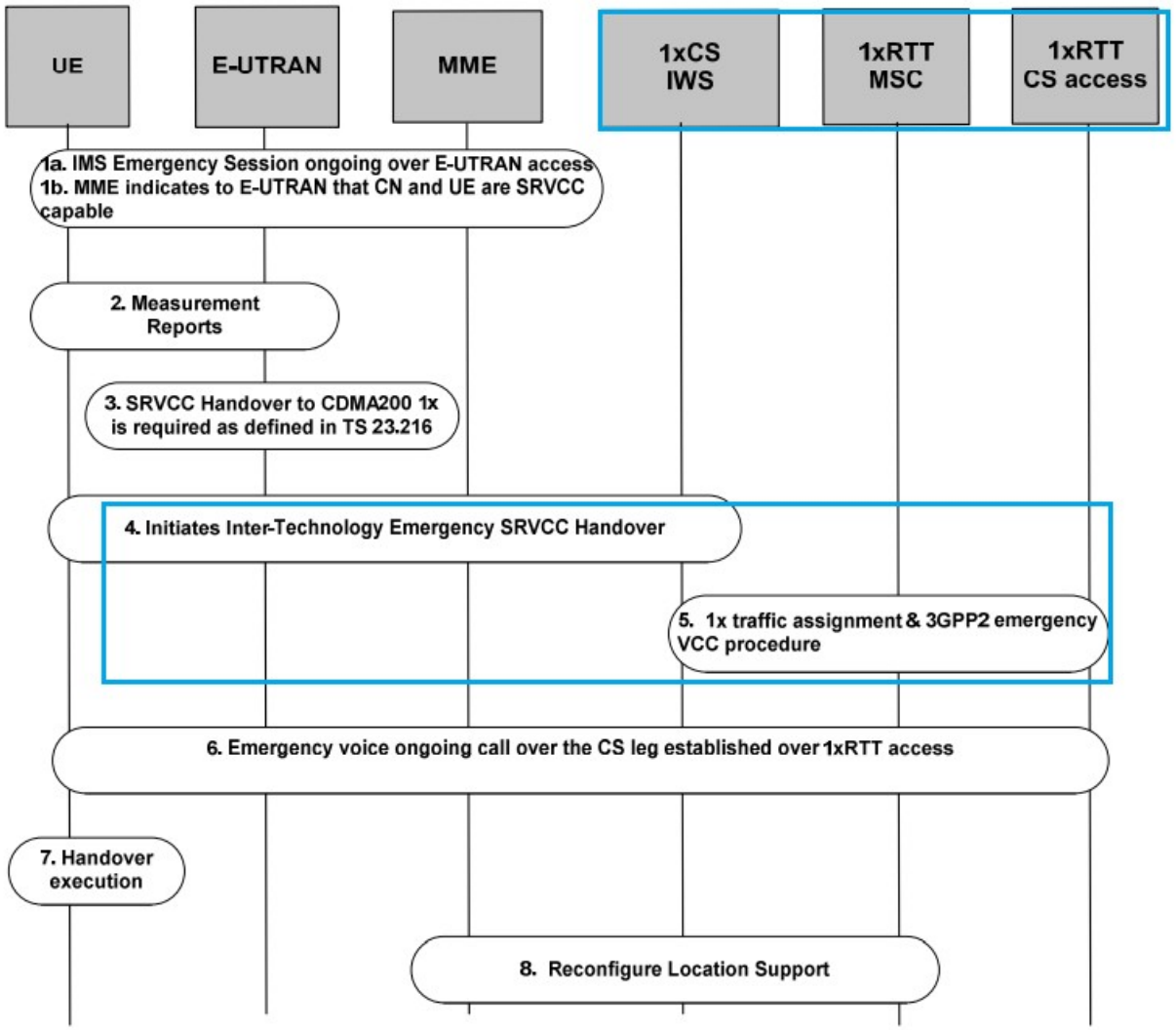


Figure 4.2.4.2-1: E-UTRAN to 3GPP2 1xCS

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

Figure 6.1.3-1 illustrates a high-level call flow for the E-UTRAN-to-1x voice service continuity procedure.

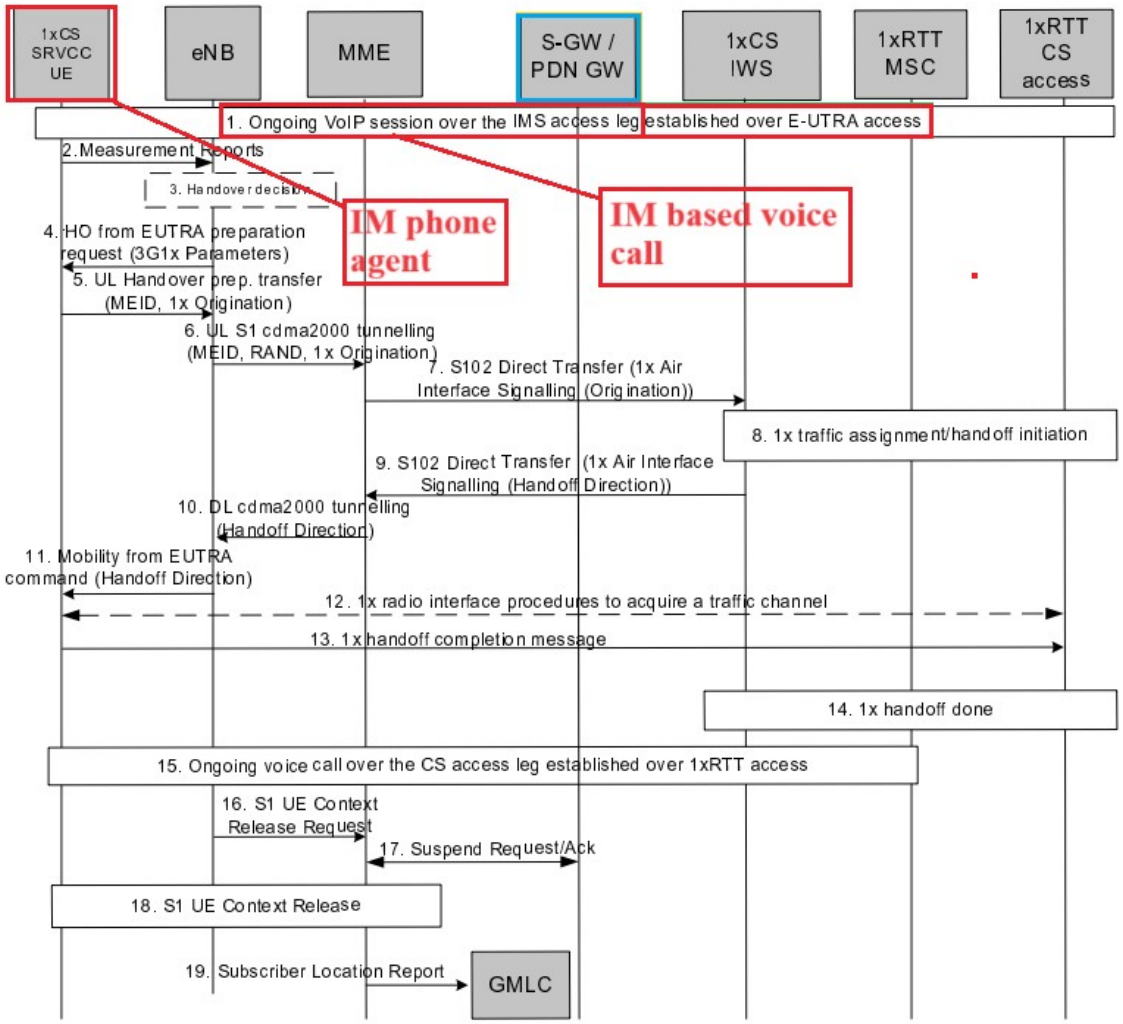


Figure 6.1.3-1: LTE VoIP-to-1x CS voice service continuity

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/

	ts_123216v160400p.pdf 5. The UE initiates signalling for establishment of the CS access leg by sending a UL handover preparation Transfer message containing the 1xRTT Origination message. For the case of emergency voice service continuity, the request includes a Request-Type = "emergency handover" and the MEID (e.g. IMEI) is included. 6. The E-UTRAN sends an Uplink S1 cdma2000 Tunnelling (MEID, RAND, 1x Origination, Reference CellID) message to the MME. The eNodeB will also include CDMA2000 HO Required Indication IE to Uplink S1 CDMA2000 Tunnelling message, which indicates to the MME that the handover preparation has started. 7. Upon reception of the Uplink S1 cdma2000 Tunnelling message, the MME selects a 3GPP2 1xCS IWS as specified in clause 5.3.3.1.2 and encapsulates the 1x Origination Message along with the MEID and RAND in a S102 Direct Transfer message (as "1x Air Interface Signalling"). 8. The traffic channel resources are established in the 1x RTT system and 3GPP2 1xCS procedures for initiation of Session Transfer are performed as per 3GPP2 X.S0042 [4]. NOTE 1: Step 9 and 3GPP2 1xCS procedures in step 8 are independent of each other. NOTE 2: For non-emergency session transfers, the "VDN" parameter referred to in 3GPP2 X.S0042 [4] corresponds to the STN-SR parameter defined in TS 23.237 [14]. NOTE 3: The emergency session transfer procedures and procedures for the 1x CS SRVCC UE obtaining the local emergency STN-SR will be specified by 3GPP2. 9. The 3GPP2 1xCS IWS creates a 1x message and encapsulates it in a S102 Direct Transfer message (1x message, Handover indicator). If the 3GPP2 access was able to allocate resources successfully, the 1x message is a 1x Handover Direction message and the handover indicator indicates successful resource allocation. Otherwise, the handover indicator indicates to the MME that handover preparation failed and the embedded 1x message indicates the failure to the UE. https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

	13. The Serving GW creates a new entry in its EPS Bearer table and sends a Create Session Request (IMSI, MSISDN, APN, Serving GW Address for the user plane, Serving GW TEID of the user plane, Serving GW TEID of the control plane, RAT type, Default EPS Bearer QoS, PDN Type, PDN Address, subscribed APN-AMBR, EPS Bearer Identity, Protocol Configuration Options, Handover Indication, ME Identity, User Location Information (ECGI), UE Time Zone, User CSG Information, MS Info Change Reporting support indication, PDN Charging Pause Support indication, Selection Mode, Charging Characteristics, Trace Reference, Trace Type, Trigger Id, OMC Identity, Maximum APN Restriction, Dual Address Bearer Flag, Serving Network, APN Rate Control Status) message to the PDN GW indicated by the PDN GW address received in the previous step. After this step, the Serving GW buffers any downlink packets it may receive from the PDN GW without sending a Downlink Data Notification message to the MME until it receives the Modify Bearer Request message in step 23 below. The MSISDN is included if received from the MME. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf The new MME sends an Attach Accept (GUTI, TAI List, Session Management Request (APN, PDN Type, PDN Address, EPS Bearer Identity, Protocol Configuration Options, Header Compression Configuration, Control Plane Only Indicator), NAS sequence number, NAS-MAC, IMS Voice over PS session supported Indication, Emergency Service Support indicator, LCS Support Indication, Supported Network Behaviour, Service Gap https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf

	18. If the eNodeB received an S1-AP Initial Context Setup Request the eNodeB sends the RRC Connection Reconfiguration message including the EPS Radio Bearer Identity to the UE, and the Attach Accept message will be sent along to the UE. If the eNodeB received an S1-AP Downlink NAS Transport message (e.g. containing the Attach Accept message), the eNode B sends a RRC Direct Transfer message to the UE. The UE shall store the QoS Negotiated, Radio Priority, Packet Flow Id and TI, which it received in the Session Management Request, for use when accessing via GERAN or UTRAN. The APN is provided to the UE to notify it of the APN for which the activated default bearer is associated. For further details, see TS 36.331 [37]. The UE may provide EPS Bearer QoS parameters to the application handling the traffic flow(s). The application usage of the EPS Bearer QoS is implementation dependent. The UE shall not reject the RRC Connection Reconfiguration on the basis of the EPS Bearer QoS parameters contained in the Session Management Request. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf
establishing a second voice call and including information about the second voice call in the first call record, associating the second voice call with the IM-based first	The accused product practices establishing a second voice call (e.g., UTRAN/GERAN/1xCS call) and including information about the second voice call in the first call record (e.g., APN of the VOIP call (E-UTRAN call), GUTI, Bearer information, etc.), associating the second voice call (e.g., UTRAN/GERAN/1xCS call) with the IM-based first voice call (e.g., VoIP call, VoLTE call (E-UTRAN call), etc.). As shown below, SRVCC is utilized to switch between calls on the E-UTRAN and UTRAN networks. During the handover, the E-UTRAN network surrenders the call (the initial IM-based voice call) and establishes an association with the UTRAN network (resulting in a second voice call). Upon successful call establishment on the UTRAN network (effectively creating a second voice call), a new identifier, known as the Temporary Mobile Subscriber Identity (TMSI), is assigned to the user. This signifies that the first call record is updated to reflect this new identifier corresponding to the mobile device on the UTRAN network (specifically, the TMSI assigned to the voice call).

voice call,

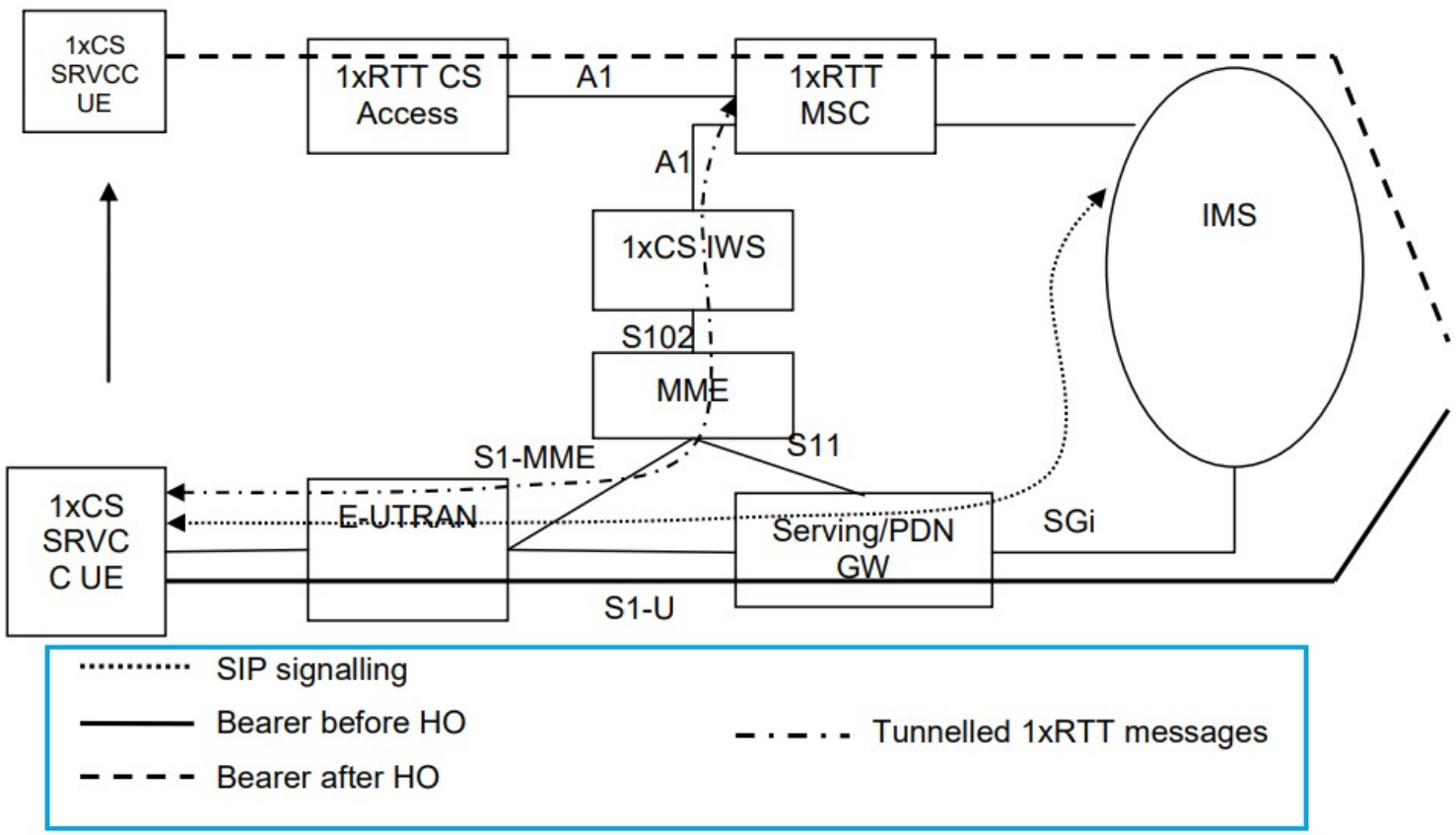


Figure 5.2.1-1: SRVCC architecture for E-UTRAN to 3GPP2 1xCS

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

When E-UTRAN determines that SRVCC is needed, the MME invokes SRVCC procedures to the 1xCS IWS including the UE's equipment identifier.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/

ts_123216v160400p.pdf

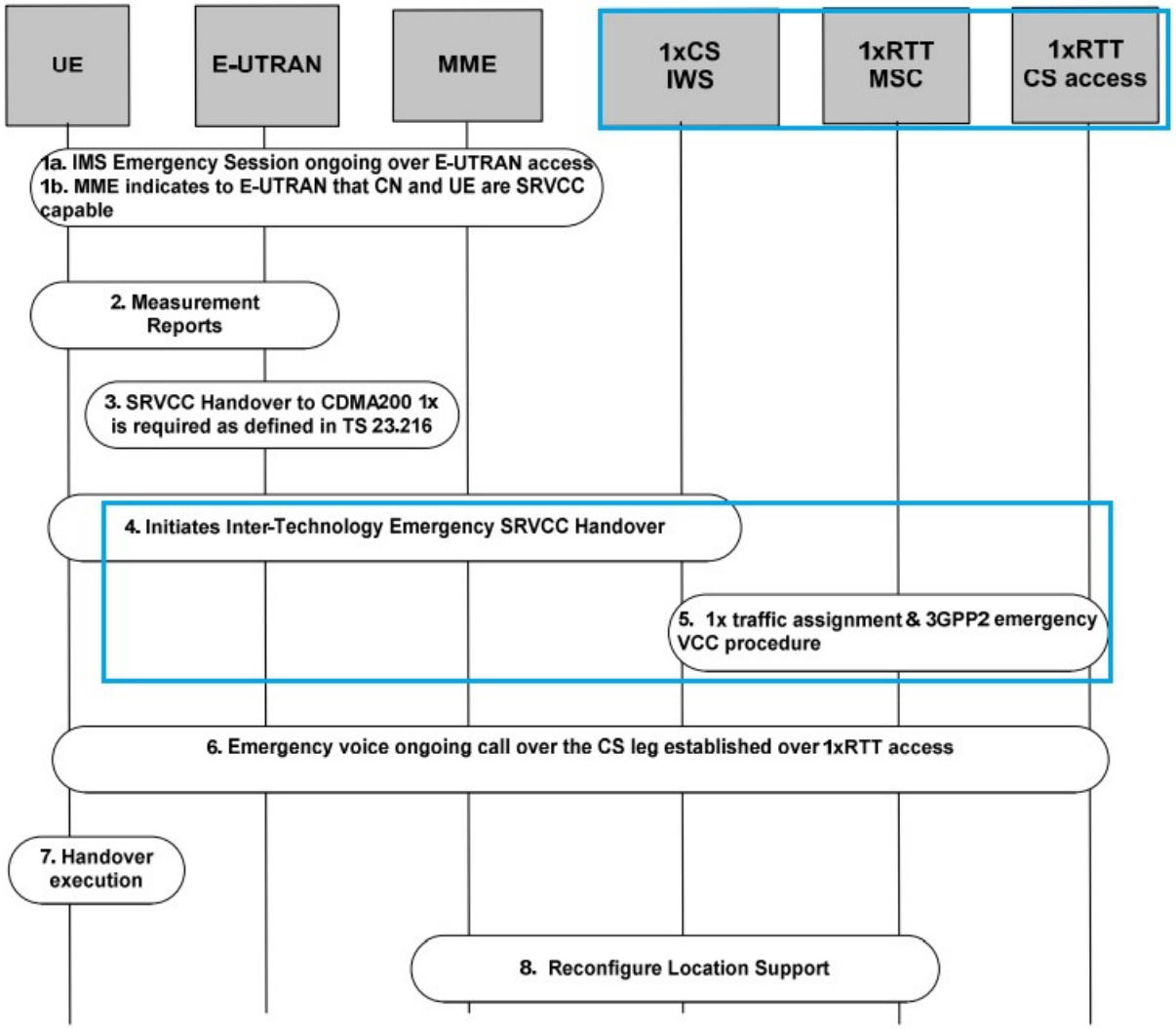


Figure 4.2.4.2-1: E-UTRAN to 3GPP2 1xCS

	https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

Figure 6.1.3-1 illustrates a high-level call flow for the E-UTRAN-to-1x voice service continuity procedure.

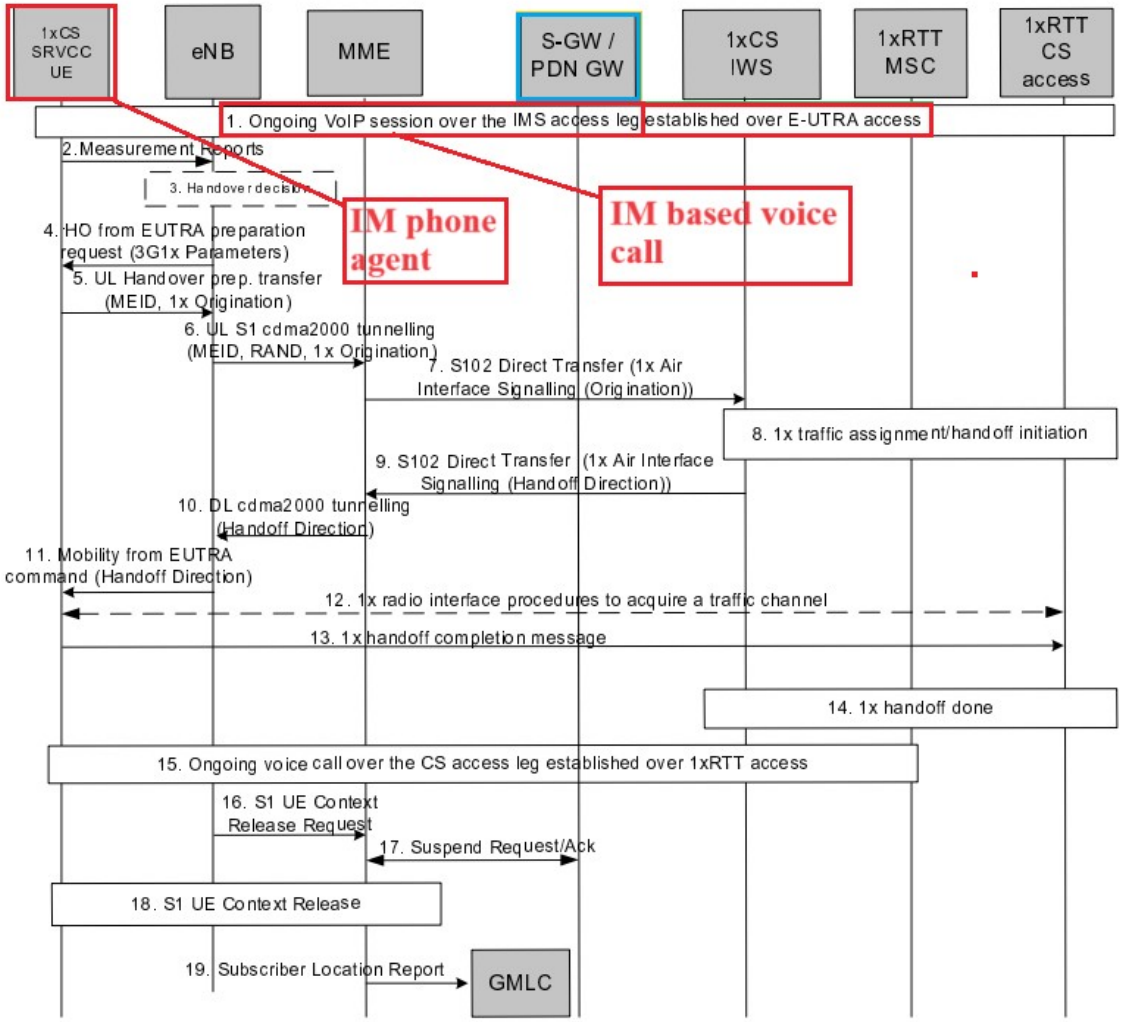


Figure 6.1.3-1: LTE VoIP-to-1x CS voice service continuity

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

5. The UE initiates signalling for establishment of the CS access leg by sending a UL handover preparation Transfer message containing the 1xRTT Origination message. For the case of emergency voice service continuity, the request includes a Request-Type = "emergency handover" and the MEID (e.g. IMEI) is included.

6. The E-UTRAN sends an Uplink S1 cdma2000 Tunnelling (MEID, RAND, 1x Origination, Reference CellID) message to the MME. The eNodeB will also include CDMA2000 HO Required Indication IE to Uplink S1 CDMA2000 Tunnelling message, which indicates to the MME that the handover preparation has started.

7. Upon reception of the Uplink S1 cdma2000 Tunnelling message, the MME selects a 3GPP2 1xCS IWS as specified in clause 5.3.3.1.2 and encapsulates the 1x Origination Message along with the MEID and RAND in a S102 Direct Transfer message (as "1x Air Interface Signalling").

8. The traffic channel resources are established in the 1x RTT system and 3GPP2 1xCS procedures for initiation of Session Transfer are performed as per 3GPP2 X.S0042 [4].

NOTE 1: Step 9 and 3GPP2 1xCS procedures in step 8 are independent of each other.

NOTE 2: For non-emergency session transfers, the "VDN" parameter referred to in 3GPP2 X.S0042 [4] corresponds to the STN-SR parameter defined in TS 23.237 [14].

NOTE 3: The emergency session transfer procedures and procedures for the 1x CS SRVCC UE obtaining the local emergency STN-SR will be specified by 3GPP2.

9. The 3GPP2 1xCS IWS creates a 1x message and encapsulates it in a S102 Direct Transfer message (1x message, Handover indicator). If the 3GPP2 access was able to allocate resources successfully, the 1x message is a 1x Handover Direction message and the handover indicator indicates successful resource allocation. Otherwise, the handover indicator indicates to the MME that handover preparation failed and the embedded 1x message indicates the failure to the UE.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

23a. For non-emergency sessions and if the HLR is to be updated, i.e. if the IMSI is authenticated but unknown in the VLR, the MSC Server performs a TMSI reallocation towards the UE using its own non-broadcast LAI and, if the MSC Server and other MSC/VLRs serve the same (target) LAI, with its own Network Resource Identifier (NRI).

NOTE 8: The TMSI reallocation is performed by the MSC Server towards the UE via target MSC.

NOTE 9: For emergency services sessions the HLR will not be updated. TMSI reallocation may be performed based on IMSI presence.

23b. For non-emergency sessions and if the MSC Server performed a TMSI reallocation in step 23a, and if this TMSI reallocation was completed successfully, the MSC Server performs a MAP Update Location to the HSS/HLR.

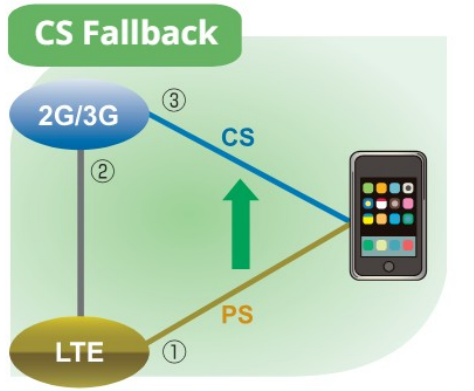
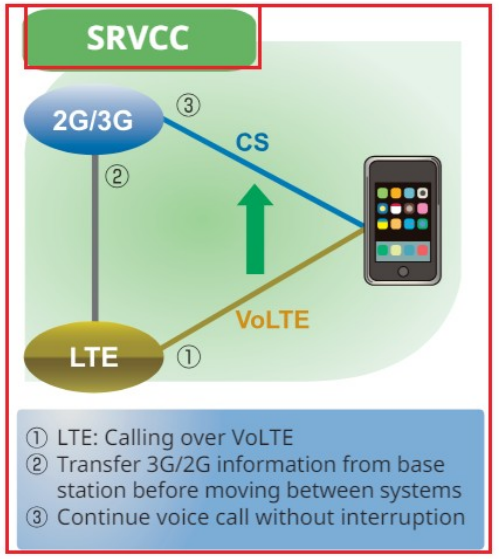
NOTE 10: This Update Location is not initiated by the UE.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

13. The Serving GW creates a new entry in its EPS Bearer table and sends a Create Session Request (IMSI, MSISDN, APN, Serving GW Address for the user plane, Serving GW TEID of the user plane, Serving GW TEID of the control plane, RAT type, Default EPS Bearer QoS, PDN Type, PDN Address, subscribed APN-AMBR, EPS Bearer Identity, Protocol Configuration Options, Handover Indication, ME Identity, User Location Information (ECGI), UE Time Zone, User CSG Information, MS Info Change Reporting support indication, PDN Charging Pause Support indication, Selection Mode, Charging Characteristics, Trace Reference, Trace Type, Trigger Id, OMC Identity, Maximum APN Restriction, Dual Address Bearer Flag, Serving Network, APN Rate Control Status) message to the PDN GW indicated by the PDN GW address received in the previous step. After this step, the Serving GW buffers any downlink packets it may receive from the PDN GW without sending a Downlink Data Notification message to the MME until it receives the Modify Bearer Request message in step 23 below. The MSISDN is included if received from the MME.

https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf

	The new MME sends an Attach Accept (GUTI, TAI List, Session Management Request (APN, PDN Type, PDN Address, EPS Bearer Identity, Protocol Configuration Options, Header Compression Configuration, Control Plane Only Indicator), NAS sequence number, NAS-MAC, IMS Voice over PS session supported Indication, Emergency Service Support indicator, LCS Support Indication, Supported Network Behaviour, Service Gap https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf 18. If the eNodeB received an S1-AP Initial Context Setup Request the eNodeB sends the RRC Connection Reconfiguration message including the EPS Radio Bearer Identity to the UE, and the Attach Accept message will be sent along to the UE. If the eNodeB received an S1-AP Downlink NAS Transport message (e.g. containing the Attach Accept message), the eNode B sends a RRC Direct Transfer message to the UE. The UE shall store the QoS Negotiated, Radio Priority, Packet Flow Id and TI, which it received in the Session Management Request, for use when accessing via GERAN or UTRAN. The APN is provided to the UE to notify it of the APN for which the activated default bearer is associated. For further details, see TS 36.331 [37]. The UE may provide EPS Bearer QoS parameters to the application handling the traffic flow(s). The application usage of the EPS Bearer QoS is implementation dependent. The UE shall not reject the RRC Connection Reconfiguration on the basis of the EPS Bearer QoS parameters contained in the Session Management Request. https://www.etsi.org/deliver/etsi_ts/123400_123499/123401/16.08.00_60/ts_123401v160800p.pdf
sending a signal to a phone agent indicating that the second voice call is for switch	The accused product practices sending a signal (e.g., sending E-UTRAN command message to UE) to a phone agent (e.g., SRVCC enabled UE device) indicating that the second voice call (e.g., UTRAN/GERAN/1xCS call) is for switch over purpose (e.g., handover from E-UTRAN call to UTRAN/GERAN/1xCS call), and establishing the second voice call (e.g., establishing a UTRAN/GERAN/1xCS voice call). As shown below, the user equipment (phone agent) is notified via a command message that the call is being switched from the initial IM-based network (E-UTRAN) to a different network (UTRAN) specifically for handover purposes. Subsequently, a second voice call using the

over purpose, and establishing the second voice call.	UTRAN network is established. **Signalling Tester MD8475B Applications** **Voice Call Evaluation Environment** **Testing Voice Calls from LTE to 3G/2G** A variety of technologies are used when a UE moves between systems from an LTE to 3G/2G cell. Configuring a 2-cell test environment using SmartStudio supports LTE and 2G/3G system voice call tests such as CS Fallback and SV-LTE (Simultaneous Voice and LTE).   https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

Signalling Tester MD8475B SmartStudio Test Functions

SmartStudio

✓: Supported

Function		Description	MD8475B LTE	MD8475B W-CDMA*2	MD8475B GSM*2	MD8475B TD-SCDMA*2
General						
	Position Registration*1	Connects UE and creates test environment	✓	✓	✓	✓
	L1/L2 Counter	Counts values for each L1/L2 channel every second	✓	✓	–	✓
	Throughput Counter	Simultaneously displays PHY layer and IP Throughput (SDU)	✓	✓	✓	✓
	Trace	Displays events for each layer as arrows	✓	✓	✓	✓
	Reject	Returns arbitrary reject message when UE connected	✓	✓	✓	✓
	Neighbor Cell Setting	Reports information to UE about BTS adjacent to BTS under test	✓	✓	✓	✓
	RF Related					
		TRx Power Setting	Changes TRx power of BTS during Idle Communication	✓	✓	✓	✓
		No Network Setting	Sets BTS Power output to OFF and switches UE to no network status	✓	✓	✓	✓
		RF Monitor	Displays frequency, frequency error, and power for each channel such as PDSCH, PUSCH, etc.	✓	✓	✓	✓
		TPC Setting	Changes TPC (Transmit Power Control) arbitrarily	✓	✓	✓	✓
		AWGN	Sends AWGN in conjunction with normal signal	✓	✓	–	–
		RF Measurement Options	Measures UE RF power at each second	✓	✓	✓	–
	External Control					
		Ethernet	Controls SmartStudio operation (parameter selection, start, etc.) from external PC	✓	✓	✓	✓
		GPIB	Controls SmartStudio setting parameters from external PC	✓	✓	✓	✓
Voice/Video Communications						
	LTE FDD/TDD					
		VoLTE/Video Telephony Calling/Answering (Loopback)	Executes call test for UE supporting Voice over LTE/Video over LTE	✓			
		Emergency Call/Originating System	Sets emergency call, and VoLTE/Video call control at LTE	✓			
		Codec Change	Changes audio and video codecs arbitrarily and executes UE switchover test	✓			
	LTE FDD/TDD, W-CDMA, GSM, TD-SCDMA					
		CSFB/eCSFB*3	Auto-switches communication method when other system voice call received during LTE call	✓	✓	✓	✓
		SRVCC*3	Performs seamless switch to CS voice call during VoLTE call	✓	✓	✓	–

https://dl.cdn-anritsu.com/en-en/test-measurement/files/Brochures-Datasheets-Catalogs/Brochure/md8475b-e1400.pdf

13. Source MME synchronises the two prepared relocations and sends a Handover Command (Target to Source Transparent Container) message to the source E-UTRAN.

NOTE 8: When the target cell is GERAN, the MME may receive different Target to Source Transparent Containers from the MSC Server and from the SGSN, i.e. a "New BSS to Old BSS Information" (see TS 48.008 [23]) may be received from the MSC Server and a "Target BSS to Source BSS Transparent Container" (see TS 48.018 [24]) may be received from the SGSN.

14. E-UTRAN sends a Handover from E-UTRAN Command message to the UE.

14a. If the PLMN has configured Secondary RAT usage data reporting and the source eNodeB has Secondary RAT usage data to report, the reporting is performed as specified in TS 23.401 [2].

15. UE tunes to the target UTRAN/GERAN cell.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

23a. For non-emergency sessions and if the HLR is to be updated, i.e. if the IMSI is authenticated but unknown in the VLR, the MSC Server performs a TMSI reallocation towards the UE using its own non-broadcast LAI and, if the MSC Server and other MSC/VLRs serve the same (target) LAI, with its own Network Resource Identifier (NRI).

NOTE 8: The TMSI reallocation is performed by the MSC Server towards the UE via target MSC.

NOTE 9: For emergency services sessions the HLR will not be updated. TMSI reallocation may be performed based on IMSI presence.

23b. For non-emergency sessions and if the MSC Server performed a TMSI reallocation in step 23a, and if this TMSI reallocation was completed successfully, the MSC Server performs a MAP Update Location to the HSS/HLR.

NOTE 10: This Update Location is not initiated by the UE.

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

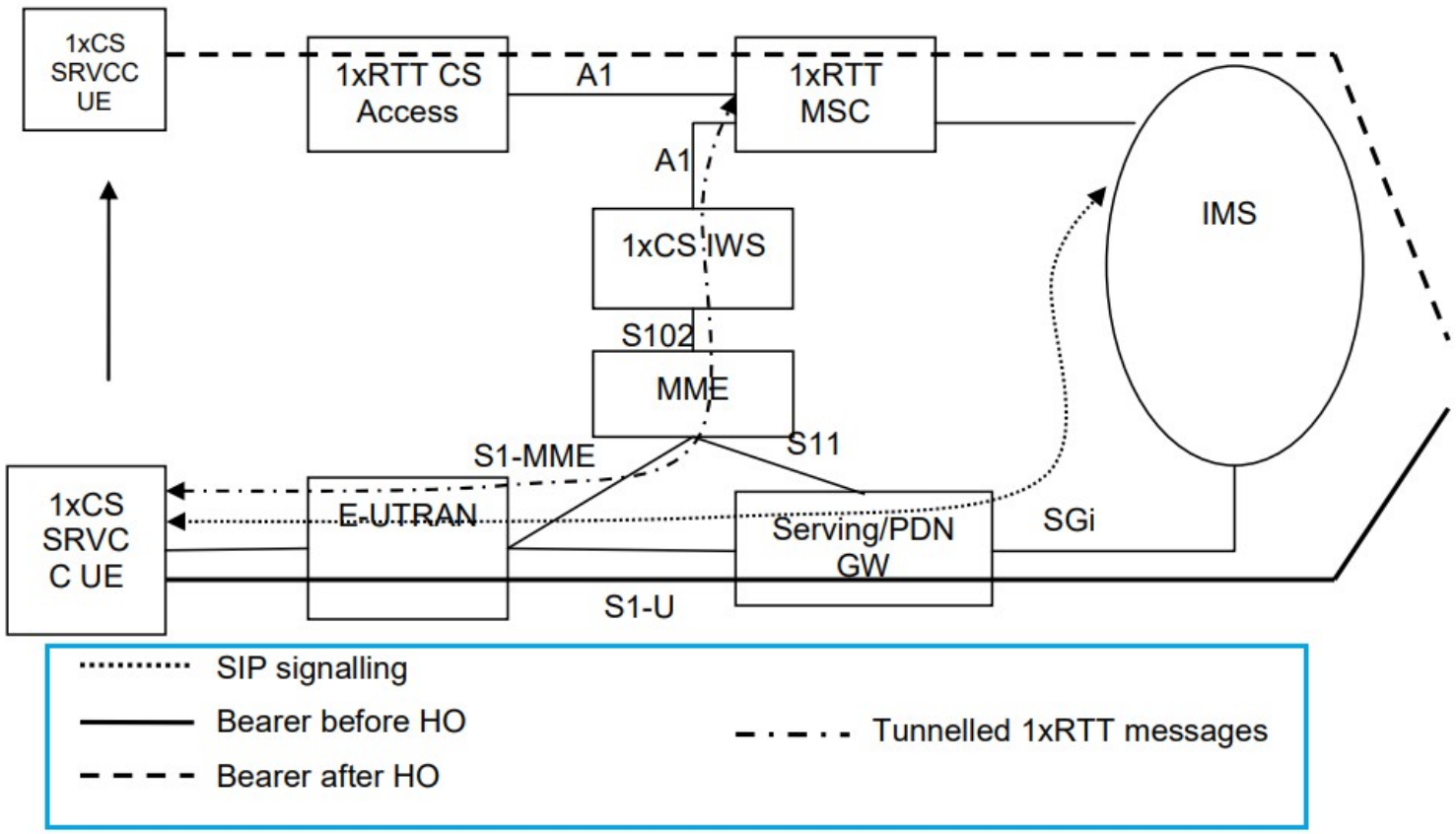


Figure 5.2.1-1: SRVCC architecture for E-UTRAN to 3GPP2 1xCS

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

When E-UTRAN determines that SRVCC is needed, the MME invokes SRVCC procedures to the 1xCS IWS including the UE's equipment identifier.

	https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

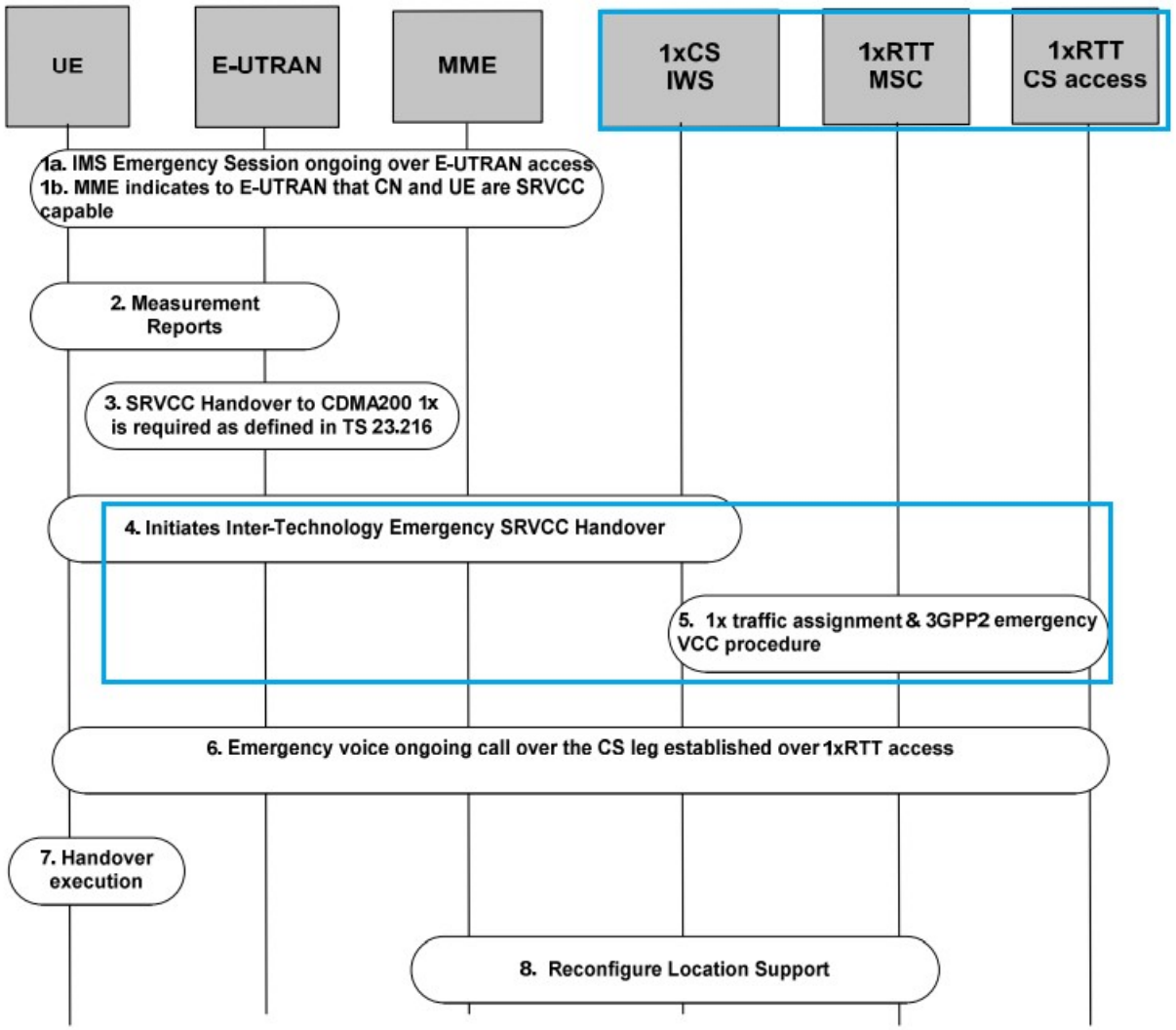


Figure 4.2.4.2-1: E-UTRAN to 3GPP2 1xCS

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/ts_123216v160400p.pdf

Figure 6.1.3-1 illustrates a high-level call flow for the E-UTRAN-to-1x voice service continuity procedure.

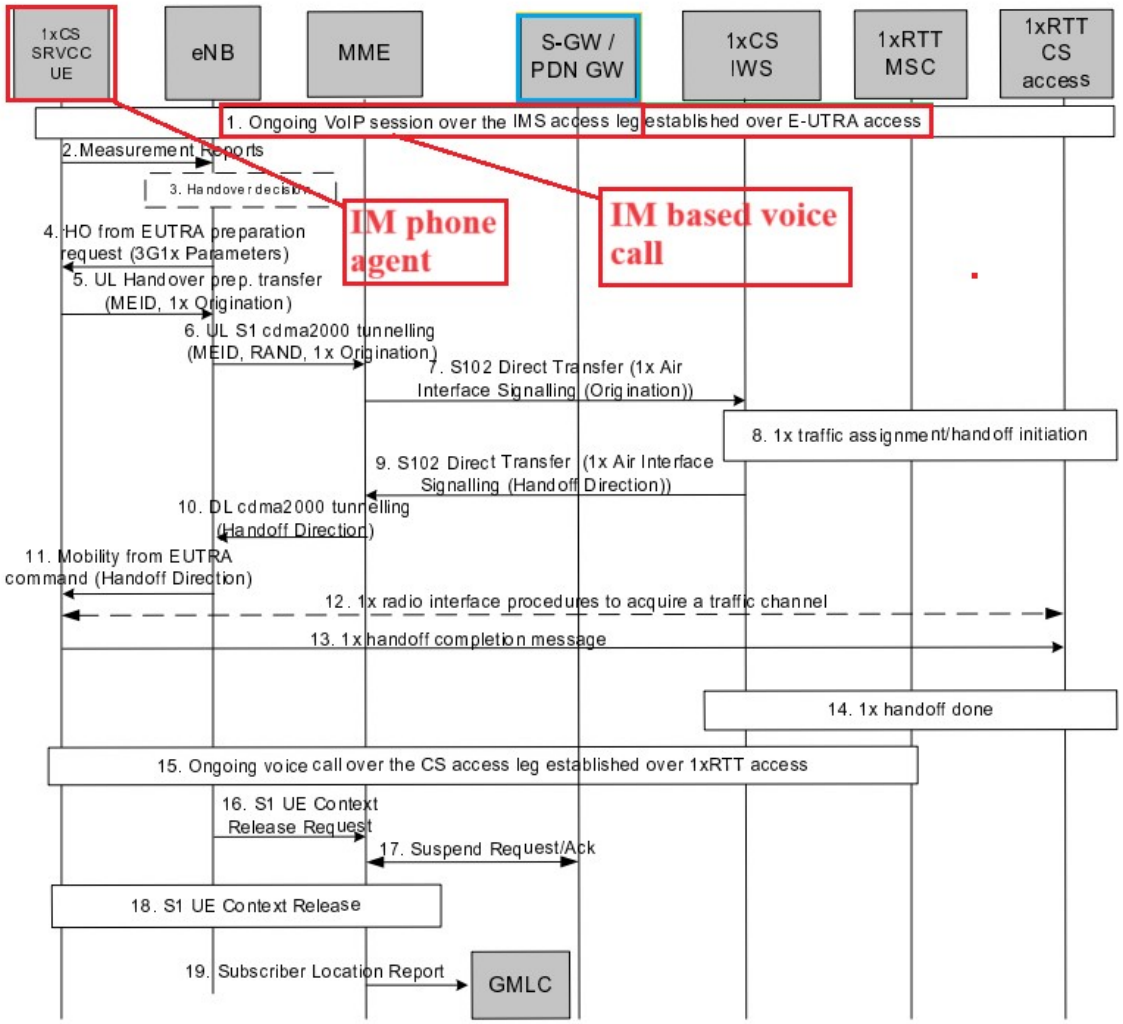


Figure 6.1.3-1: LTE VoIP-to-1x CS voice service continuity

https://www.etsi.org/deliver/etsi_ts/123200_123299/123216/16.04.00_60/

	ts_123216v160400p.pdf